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**Suzuki et al.**

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(54) **FUEL INJECTION VALVE**

(71) Applicant: **DENSO CORPORATION**, Kariya, Aichi-pref. (JP)

(72) Inventors: **Haruki Suzuki**, Kasugai (JP); **Akinori Harada**, Toyohashi (JP)

(73) Assignee: **DENSO CORPORATION**, Kariya (JP)

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*Primary Examiner* — Arthur O Hall

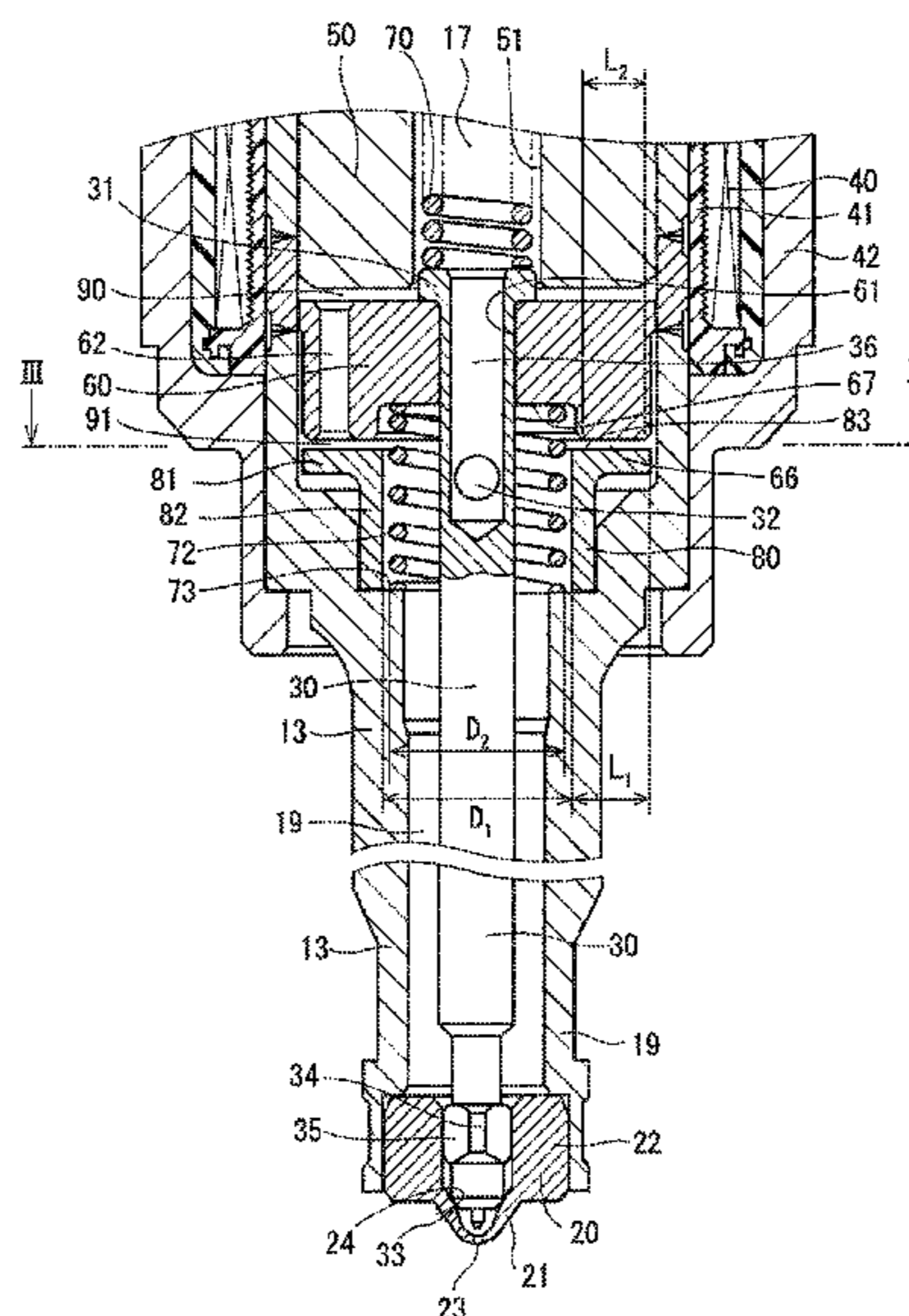
*Assistant Examiner* — Christopher R Dandridge

(74) *Attorney, Agent, or Firm* — Nixon & Vanderhye P.C.

(57) **ABSTRACT**

A first spring axially urges a needle valve toward an injection hole. A second spring axially urges a movable core toward a stationary core with an urging force that is smaller than an urging force of the first spring. A stopper is placed on one axial side of the movable core where the injection hole is located. The stopper limits movement of the movable core toward the injection hole to limit an amount of compression of the second spring.

**33 Claims, 10 Drawing Sheets**



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| (52) | <b>U.S. Cl.</b><br>CPC ..... <i>A01G 25/023</i> (2013.01); <i>F02M 45/08</i><br>(2013.01); <i>F02M 45/083</i> (2013.01); <i>F02M</i><br><i>61/168</i> (2013.01); <i>F02M 61/18</i> (2013.01);<br><i>F02M 61/1853</i> (2013.01) |  |
| (58) | <b>Field of Classification Search</b><br>USPC ..... 239/585.1, 585.3, 585.4, 585.5, 533.2<br>See application file for complete search history.   | JP 4210523 10/2008<br>JP 2010-138886 6/2010<br>JP 2011-117362 6/2011   |

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FIG. 1

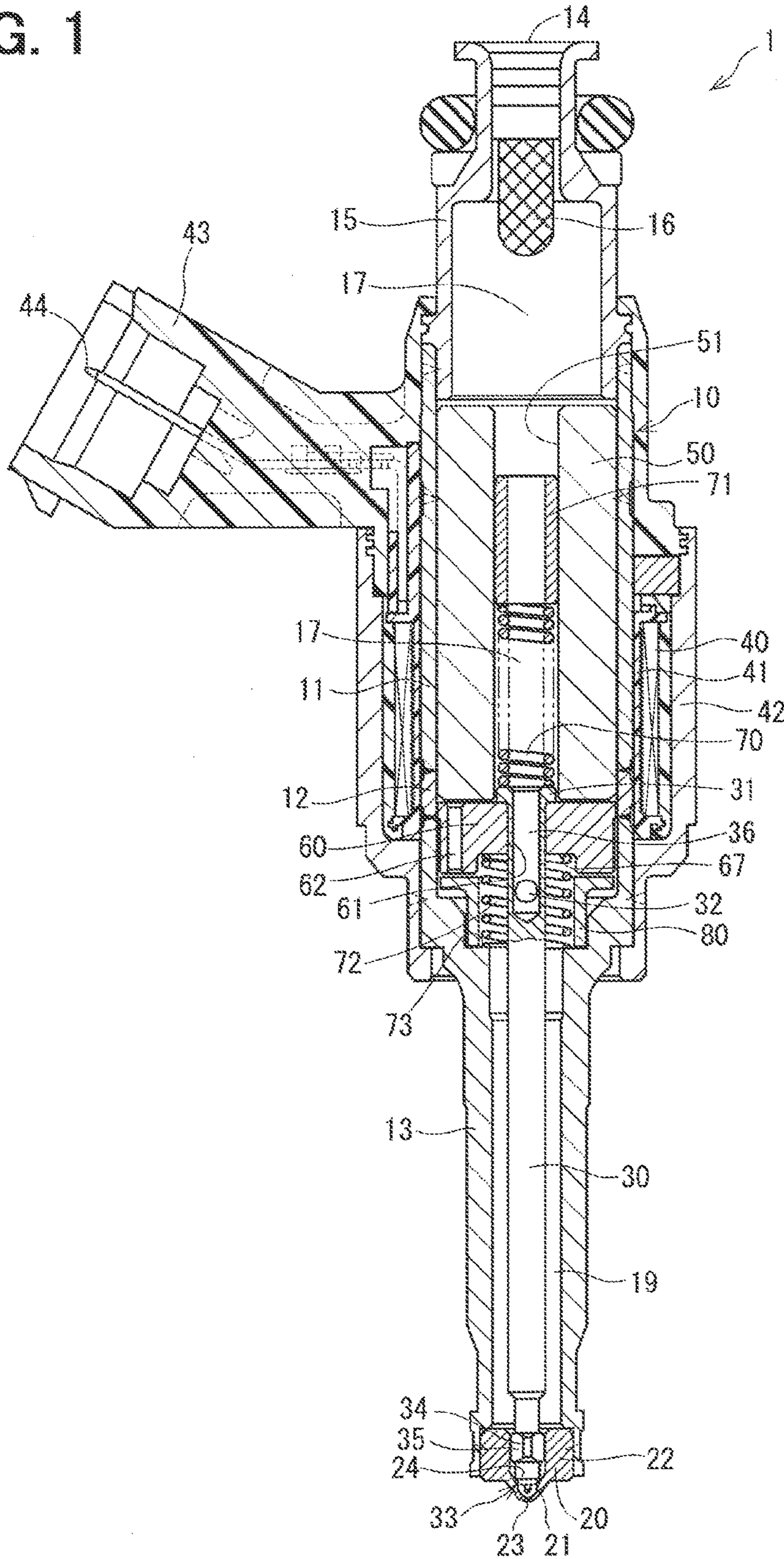


FIG. 2

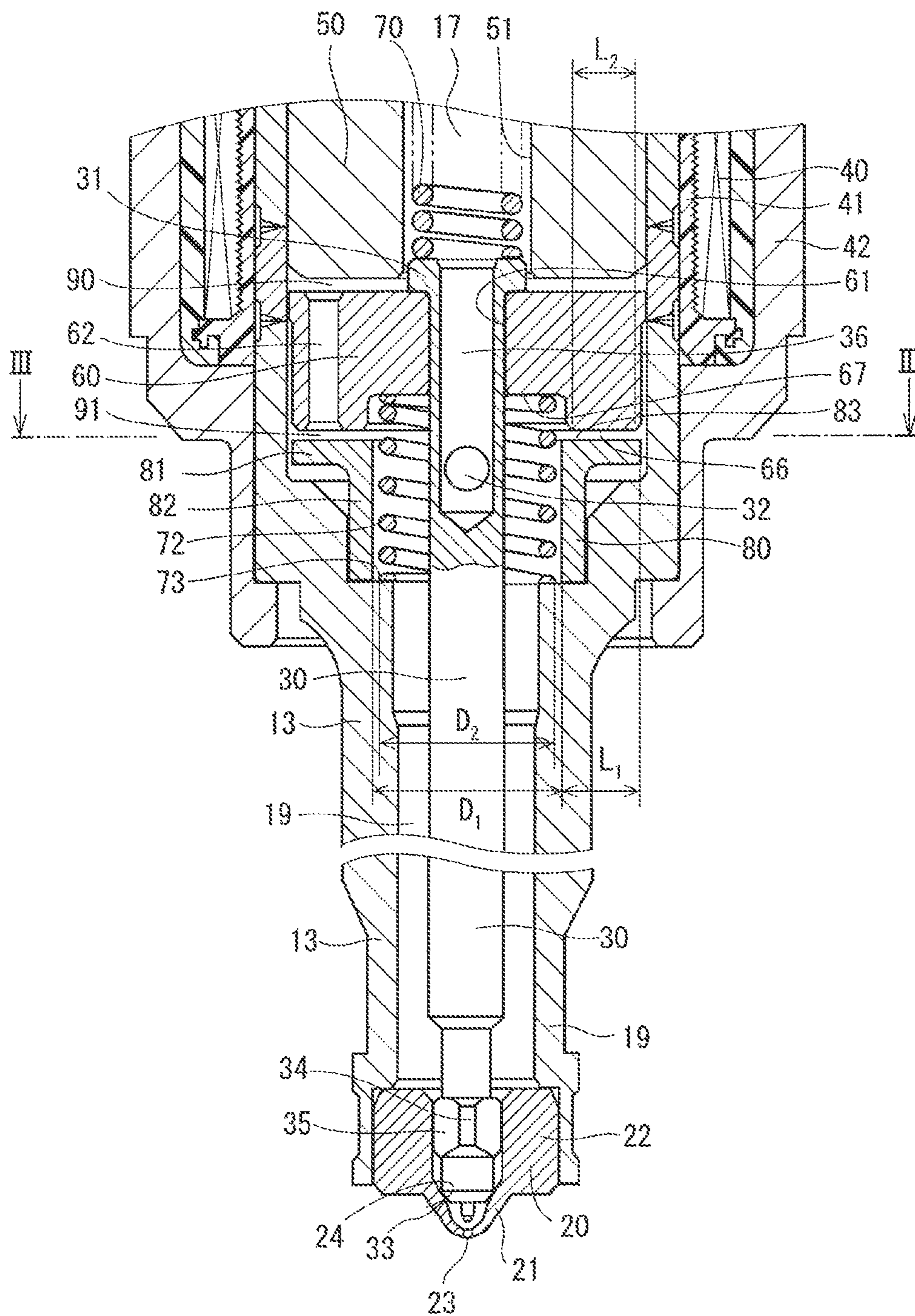


FIG. 3

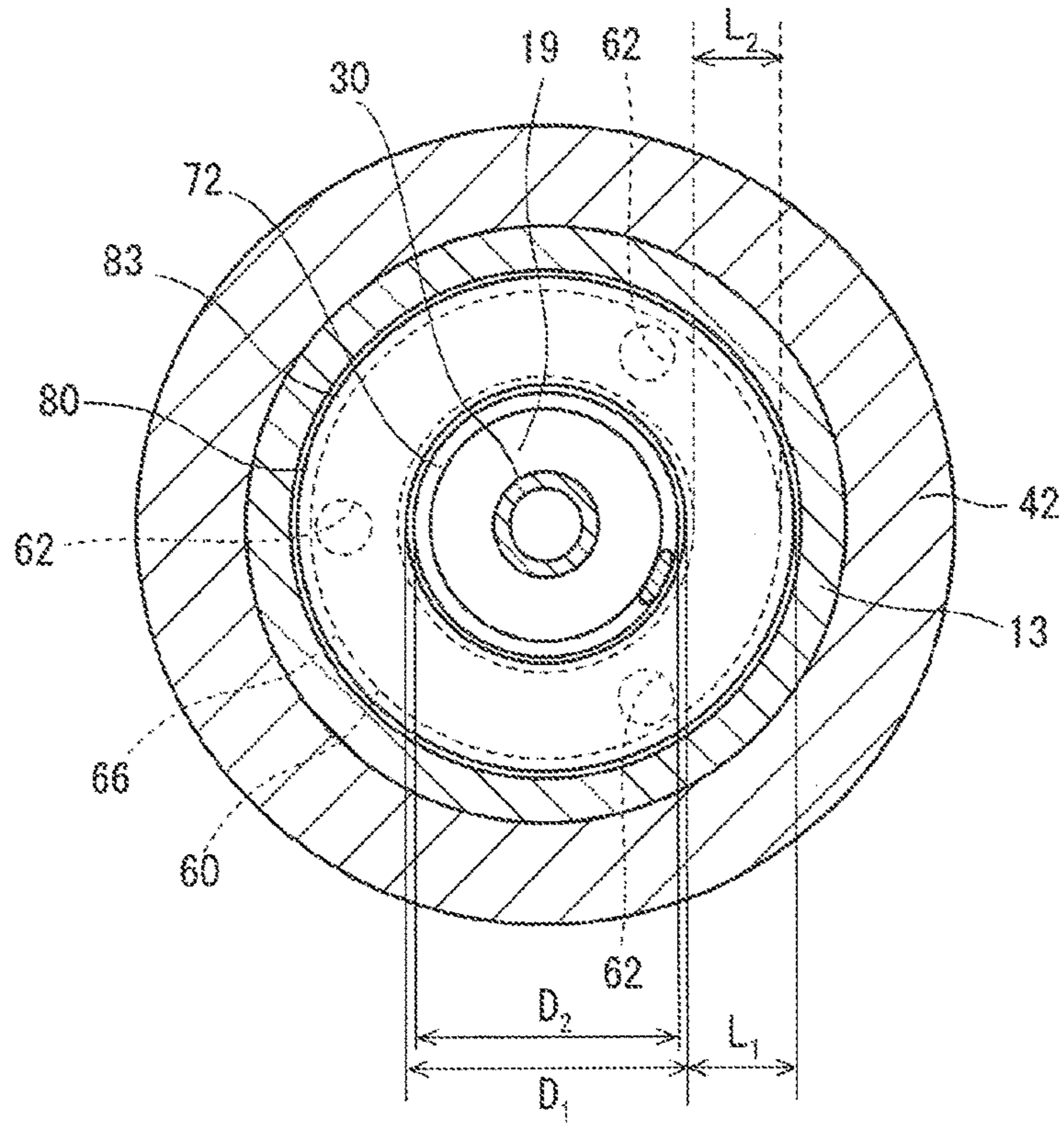


FIG. 4

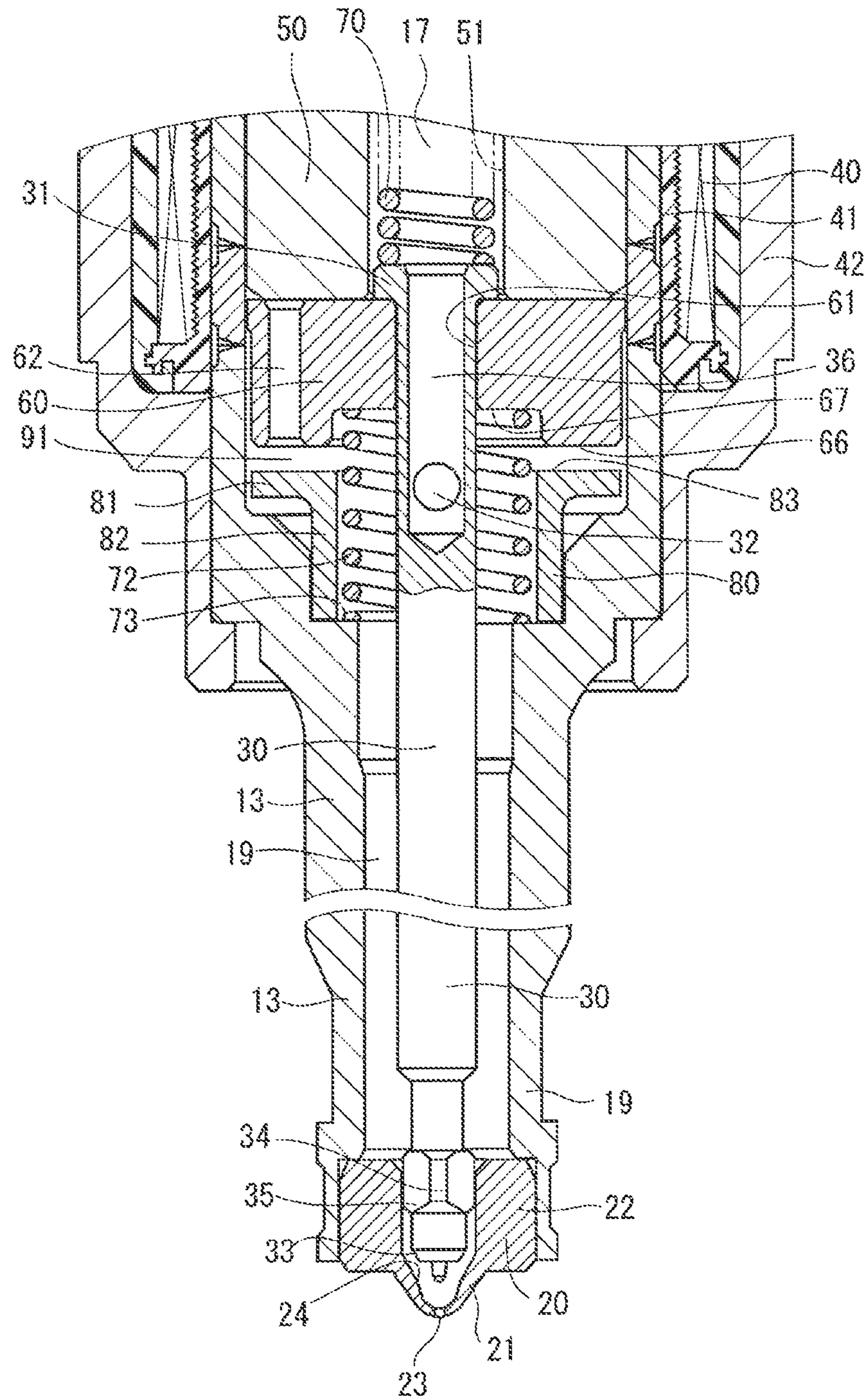


FIG. 5

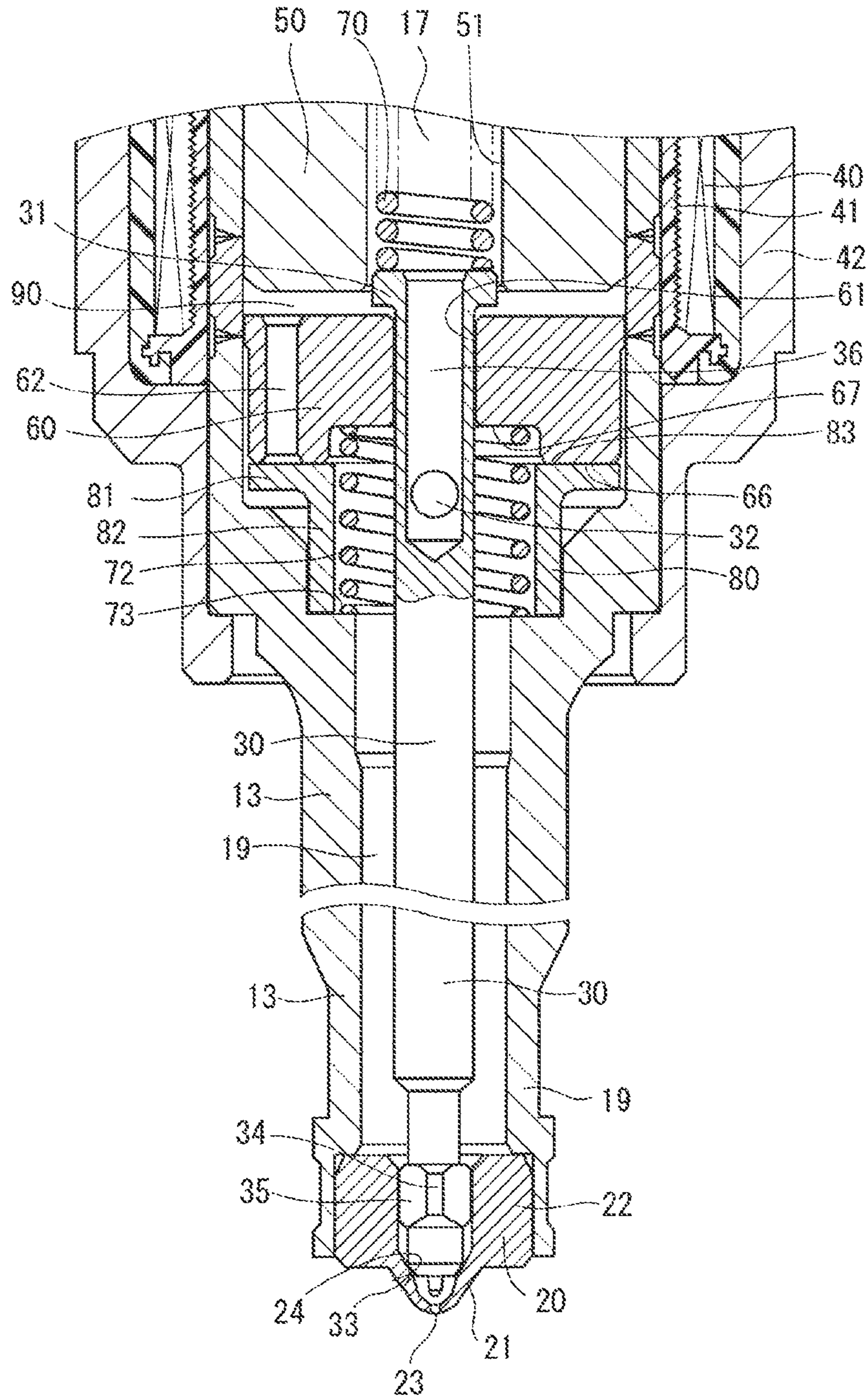


FIG. 6

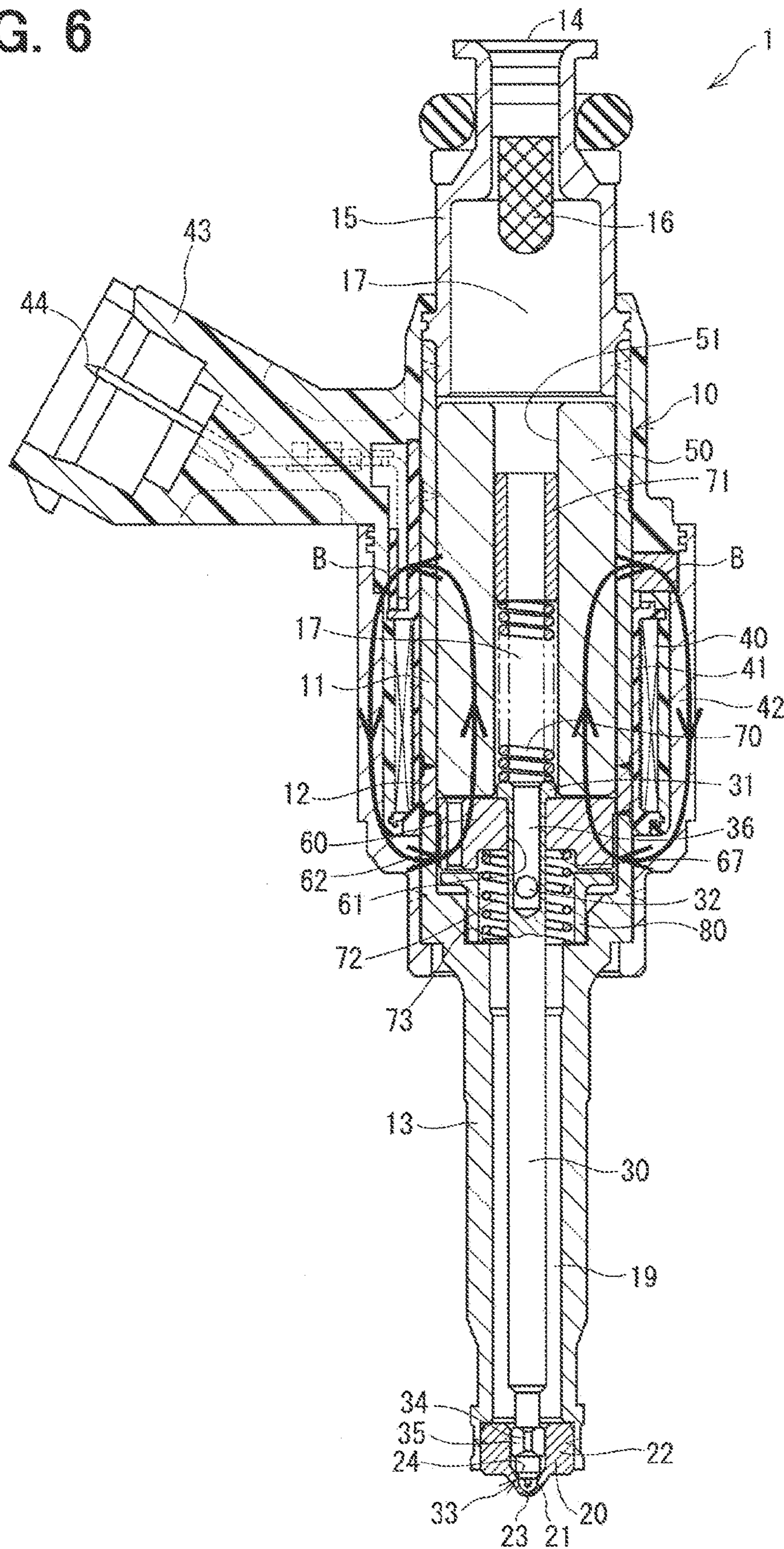




FIG. 7

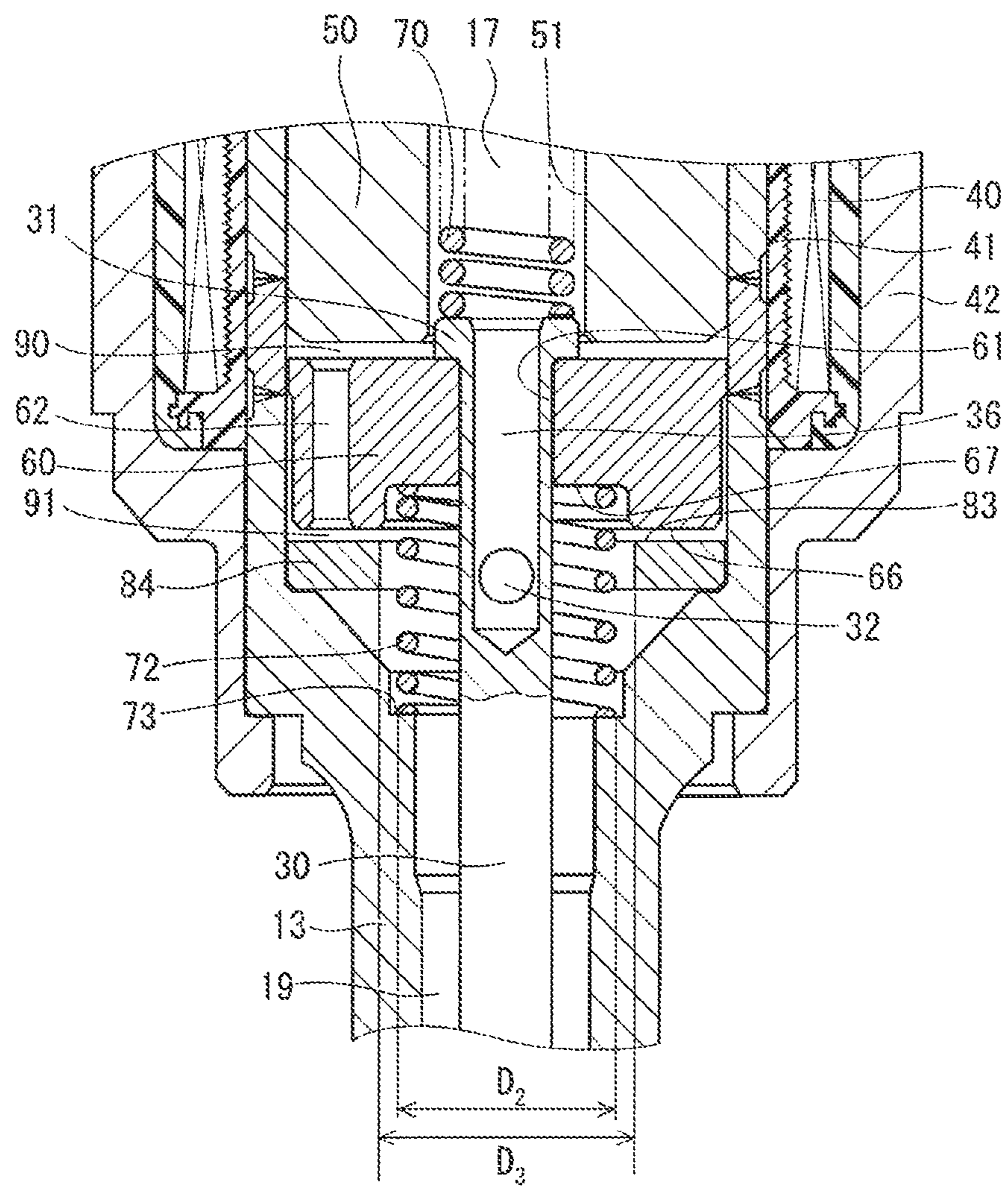


FIG. 8

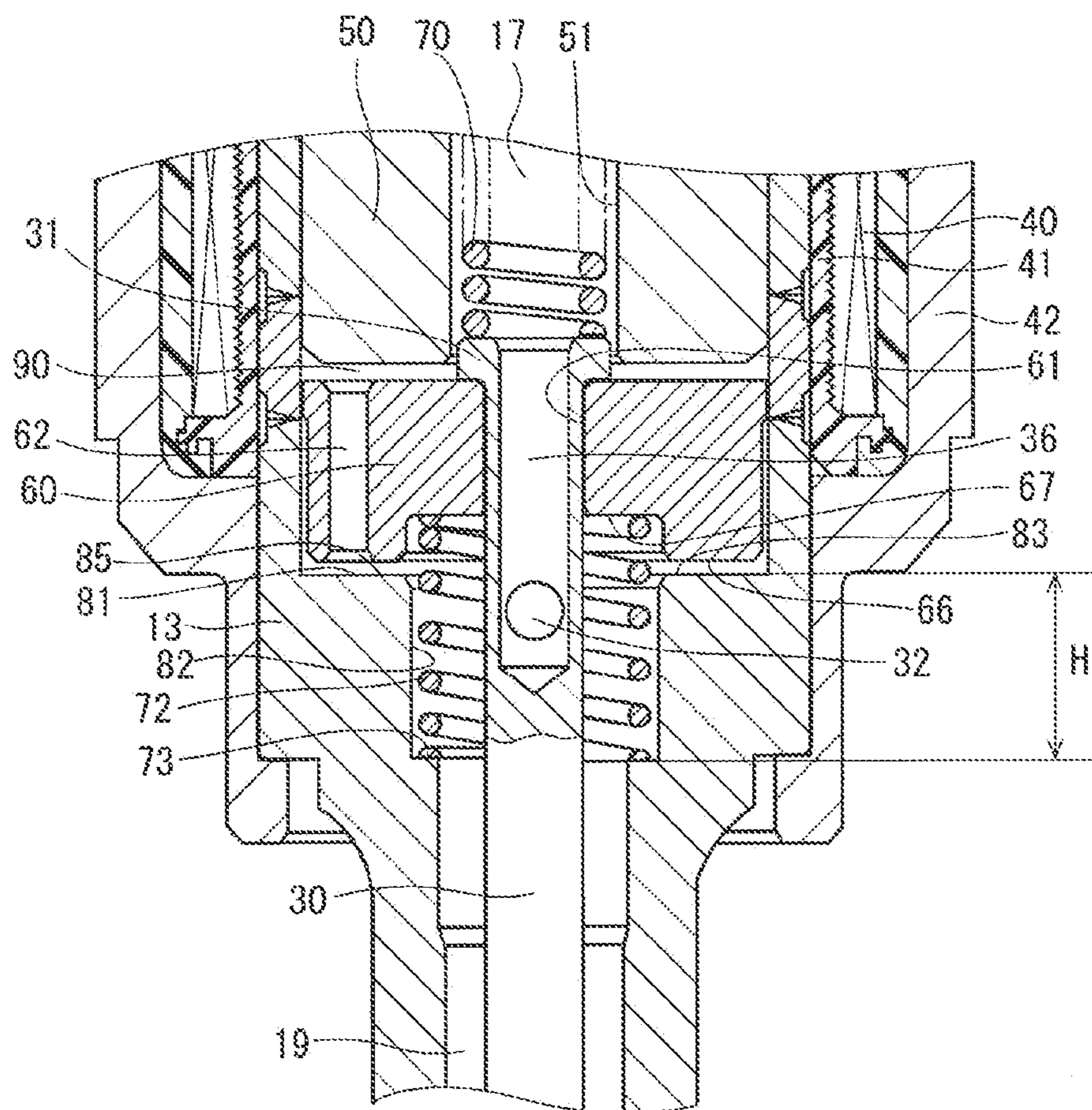


FIG. 9

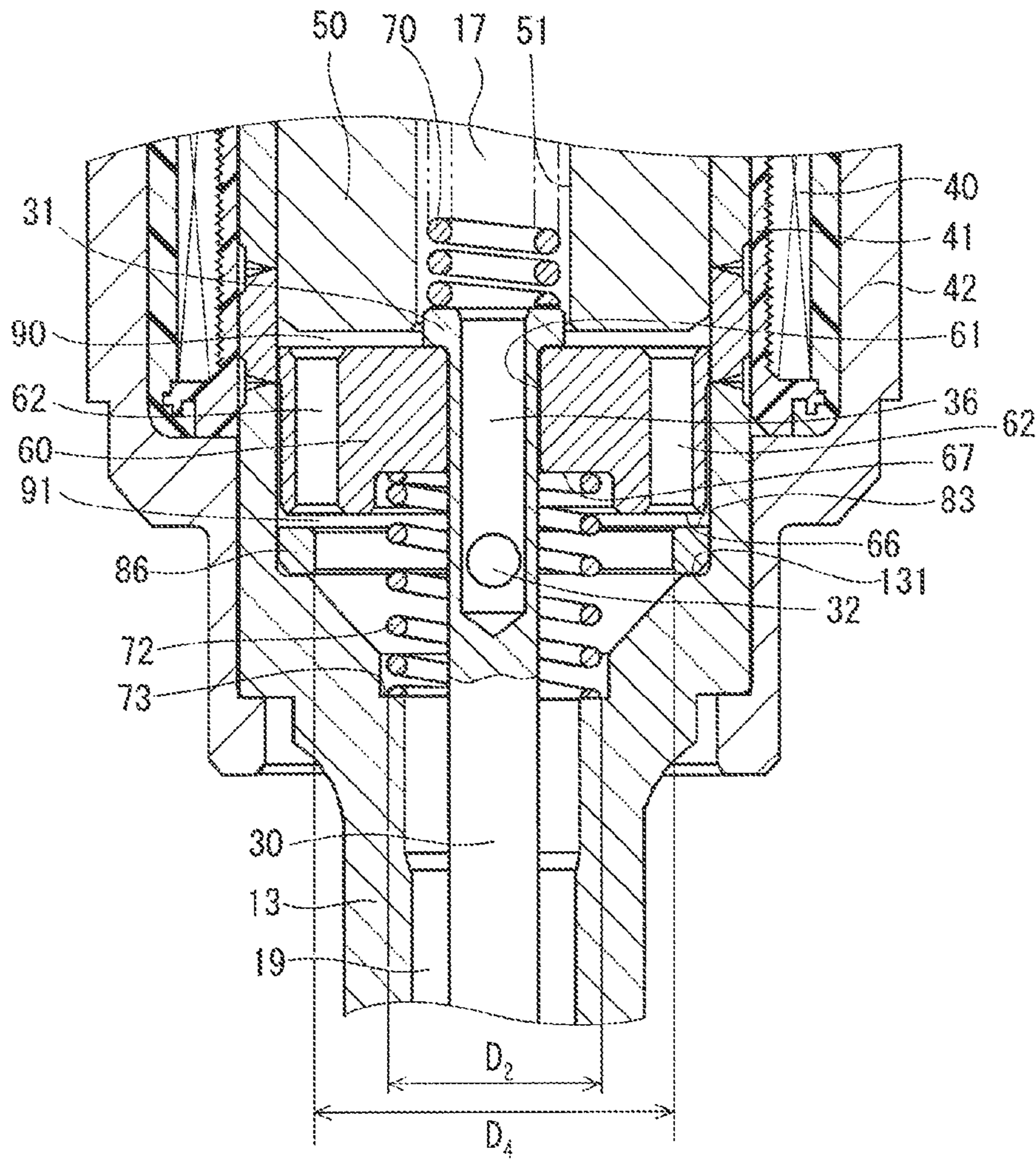
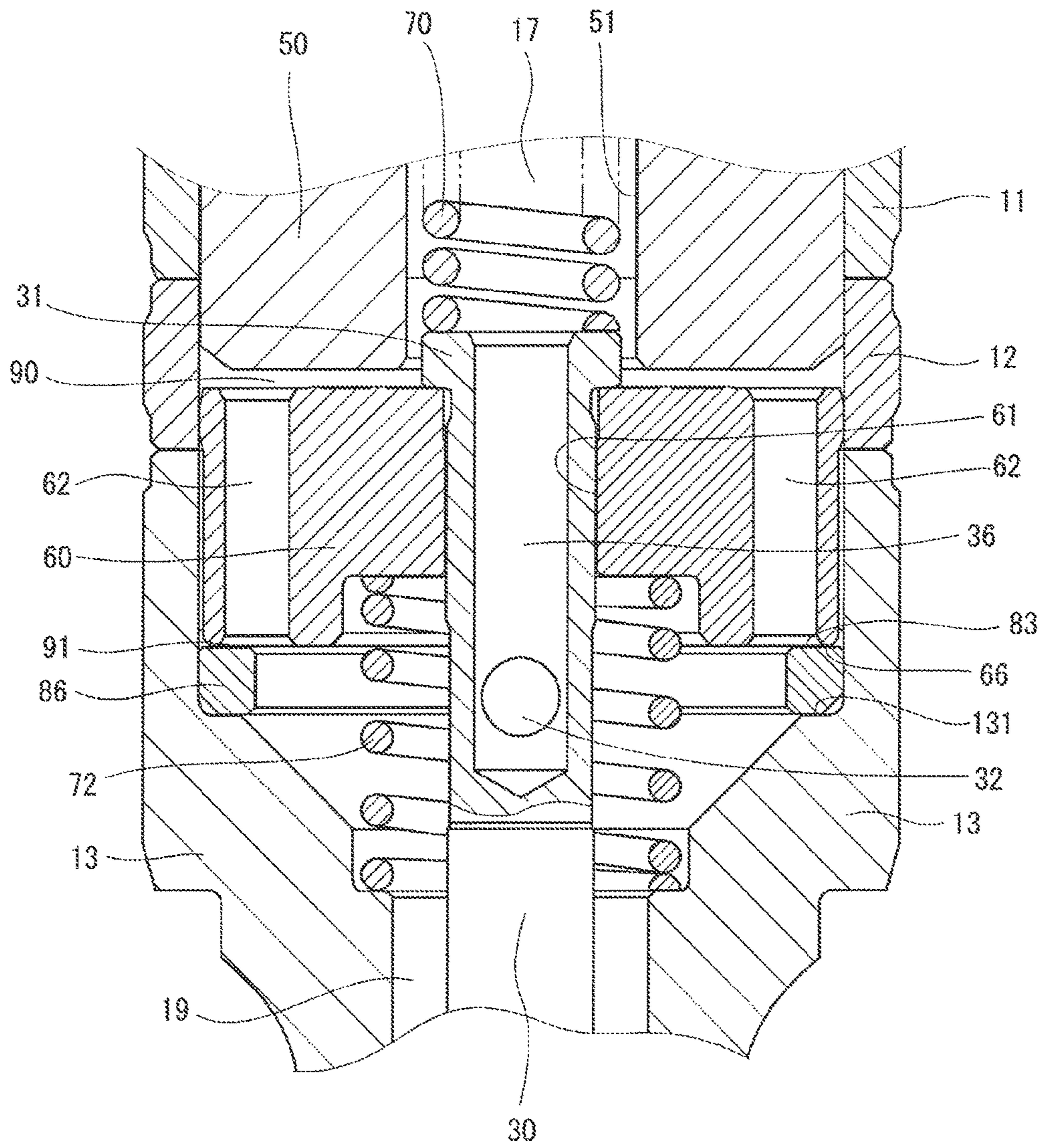


FIG. 10



## FUEL INJECTION VALVE

## CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 13/767,209, filed on Feb. 14, 2013 and is based on reference Japanese Patent Application No. 2012-33577 filed on Feb. 20, 2012 and Japanese Patent Application No. 2012-190113 filed on Aug. 30, 2012, each of which are incorporated herein by reference.

## TECHNICAL FIELD

The present disclosure relates to a fuel injection valve.

## BACKGROUND

A solenoid type fuel injection valve (injector) is known. The solenoid type fuel injection valve receives high pressure fuel from a delivery pipe, which accumulates fuel received from a high pressure pump that pumps fuel from a fuel tank. The fuel injection valve injects the received high pressure fuel into an internal combustion engine of a vehicle (e.g., an automobile).

For instance, JP2002-506502A (corresponding to U.S. Pat. No. 6,279,873B1) teaches such a fuel injection valve. Specifically, in a deenergized state of a coil of this fuel injection valve, a needle valve is urged by an urging force of a first return spring, so that the needle valve is seated against a valve seat. Furthermore, a movable core is urged against a stopper element by an urging force of a second return spring. At this time, a small gap is formed between a flange of the needle valve and the movable core.

At the time of executing a valve-opening operation, the coil is energized, so that the movable core is magnetically attracted to the stationary core, and the movable core abuts against the flange of the needle valve in the accelerated state of the movable core. In this way, a valve-opening time period, which is a time period required to open the injection hole by lifting the needle valve away from the valve seat, is shortened.

However, in the fuel injection valve of JP2002-506502A (corresponding to U.S. Pat. No. 6,279,873B1), both of the first return spring and the second return spring urge the movable core toward the fuel injection hole at the time of executing a valve-closing operation, which is executed to seat the needle valve against the valve seat. Therefore, when the state of the coil is changed from the energized state to the deenergized state, the movable core, which is moved together with the needle valve toward the injection hole, is urged by the urging force of the second return spring and the inertia of the movable core and thereby collides against the stopper element upon the seating of the needle valve against the valve seat. Thereafter, the movable core rebounds from the stopper element. When the collision force of the movable core against the flange of the needle is increased, a secondary valve-opening movement of the needle valve occurs to reopen the injection hole. Thereby, it may possibly be difficult to accurately control the fuel injection quantity of the fuel injection valve.

Furthermore, when the collision force of the movable core against the stopper element is increased, the collision noise may possibly be increased. Also, the collision of the movable core against the stopper element may possibly damage the movable core and/or the stopper element.

## SUMMARY

The present disclosure addresses the above disadvantage. According to the present disclosure, there is provided a fuel injection valve, which includes a housing, a needle valve, a coil, a stationary core, a movable core, a first spring, a second spring and a stopper. The housing is configured into a tubular body and has an injection hole, a fuel passage and a valve seat. Fuel is injected through the injection hole. The fuel passage is communicated with the injection hole. The valve seat is formed in an inner wall of the fuel passage. The needle valve is received in the housing and is axially reciprocable in the housing. The needle valve has a flange that radially outwardly projects. The needle valve opens the injection hole when the needle valve is lifted away from the valve seat. The needle valve closes the injection hole when the needle valve is seated against the valve seat. The coil generates a magnetic field in an energized state of the coil. The stationary core is fixed in the housing at a corresponding location that is within a range of the magnetic field generated from the coil. The movable core is axially reciprocable and is placed on one axial side of the stationary core where the injection hole is located. The movable core is contactable with an end surface of the flange of the needle valve, which is located on an axial side where the injection hole is located. The first spring axially urges the needle valve toward the injection hole. The second spring axially urges the movable core toward the stationary core with an urging force that is smaller than an urging force of the first spring, which axially urges the needle valve toward the injection hole. The stopper is placed on one axial side of the movable core where the injection hole is located. The stopper limits movement of the movable core toward the injection hole to limit an amount of compression of the second spring.

## BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. 1 is a cross-sectional view of a fuel injection valve according to a first embodiment of the present disclosure;

FIG. 2 is a partial enlarged cross-sectional view of FIG. 1 showing a main feature of the fuel injection valve of the first embodiment;

FIG. 3 is a cross-sectional view taken along line in FIG. 2;

FIG. 4 is a partial enlarged view of the fuel injection valve of the first embodiment, showing a valve-opening operation of the fuel injection valve;

FIG. 5 is a partial enlarged view of the fuel injection valve of the first embodiment, showing a valve-closing operation of the fuel injection valve;

FIG. 6 is a diagram showing a flow of a magnetic flux in the valve-opening operation of the fuel injection valve of the first embodiment;

FIG. 7 is a partial enlarged cross-sectional view showing a main feature of a fuel injection valve according to a second embodiment of the present disclosure;

FIG. 8 is a partial enlarged cross-sectional view showing a main feature of a fuel injection valve according to a third embodiment of the present disclosure;

FIG. 9 is a partial enlarged cross-sectional view showing a main feature of a fuel injection valve according to a fourth embodiment of the present disclosure; and

FIG. 10 is a partial enlarged cross-sectional view showing the main feature of the fuel injection valve according to the fourth embodiment.

#### DETAILED DESCRIPTION

Embodiments of the present disclosure will be described with reference to the accompanying drawings.

##### First Embodiment

FIGS. 1 to 6 show a fuel injection valve according to a first embodiment of the present disclosure. The fuel injection valve 1 receives high pressure fuel from a delivery pipe, which accumulates fuel received from a high pressure pump that pumps fuel from a fuel tank. The fuel injection valve 1 injects the received high pressure fuel into an internal combustion engine of a vehicle (e.g., an automobile).

As shown in FIGS. 1 and 2, the fuel injection valve 1 includes a housing 10, a needle valve 30, a coil 40, a stationary core 50, a movable core 60 and a stopper 80.

The housing 10 includes a tubular member 11, a non-magnetic portion 12, a holder 13, an inlet member 15 and a nozzle body 20. The housing 10 serves as a housing of the present disclosure.

The tubular member 11, the non-magnetic portion 12 and the holder 13 are configured into generally cylindrical tubular bodies, respectively, and are joined one after another in this order from a fuel inlet 14 side (i.e., an axial side where the fuel inlet 14 is located). The tubular member 11 and the holder 13 are made of a magnetic material. The non-magnetic portion 12 is made of a non-magnetic material and limits magnetic short-circuit between the tubular member 11 and the holder 13.

The inlet member 15, which is configured into a tubular body and forms the fuel inlet 14, is joined to an end portion of the tubular member 11, which is opposite from the non-magnetic portion 12. A filter 16 is placed in the inlet member 15 at a location that is radially inward of the inlet member 15. The fuel, which is supplied through the fuel inlet 14, is filtered through the filter 16 and is supplied to an upstream passage 17 that is formed in an inside of the housing 10.

The housing 10 has a nozzle body 20 at an end portion of the housing 10, which is opposite from the non-magnetic portion 12 of the holder 13. The nozzle body 20 is configured into a cup shape body and has a bottom portion (a bottom wall portion) 21 and a tubular portion (peripheral wall portion) 22. The tubular portion 22 is joined to an inner peripheral portion of the holder 13. An injection hole 23 is formed to axially extend through the bottom portion 21.

A valve seat 24, which is recessed and is tapered, is formed in an inner wall of the bottom portion 21.

The needle valve 30 is configured into a cylindrical rod body and is received in the housing 10 such that the needle valve 30 is reciprocable in the axial direction in the housing 10.

The needle valve 30 has a flange 31. The flange 31 radially outwardly projects from a fuel inlet 14 side end portion of the needle valve 30 (i.e., an end portion of the needle valve 30 located on an axial side where the fuel inlet 14 is placed). The flange 31 is configured into an annular form. The flange 31 can contact a fuel inlet 14 side end surface of the movable core 60 (i.e., an end surface of the movable core 60 located on an axial side where the fuel inlet 14 is placed).

A downstream passage 19 is radially defined between the needle valve 30 and the holder 13 and extends in the axial direction in the inside of the holder 13. The upstream passage 17 and the downstream passage 19 serve as a fuel passage of the present disclosure.

The needle valve 30 has an inside passage 36, which axially extends along a central axis of the needle valve 30. The needle valve 30 has a flow outlet 32, which radially extends through the needle valve 30 from an inner wall of the inside passage 36 to an outer wall of the needle valve 30. Thereby, the inside passage 36 communicates between the upstream passage 17 and the downstream passage 19 through the flow outlet 32.

A seat portion 33 is formed in an injection hole 23 side end portion of the needle valve 30 (i.e., an end portion of the needle valve 30 located on an axial side where the injection hole 23 is placed). The seat portion 33 is contactable with, i.e., is seatable against the valve seat 24. A slidable portion 34 is formed in the needle valve 30 at a location, which is axially spaced from the seat portion 33 by a predetermined distance. The slidable portion 34 is slidable along an inner peripheral wall of the tubular portion 22 of the nozzle body 20. A chamfered portion 35 is formed in a portion of an outer peripheral wall of the slidable portion 34. Fuel can flow between the chamfered portion 35 and the inner peripheral wall of the tubular portion 22.

When the seat portion 33 is seated against the valve seat 24, the needle valve 30 closes the downstream passage 19, which is communicated with the injection hole 23. Then, when the seat portion 33 is lifted away from the valve seat 24, the needle valve 30 opens the downstream passage 19, which is communicated with the injection hole 23.

Hereinafter, the lifting direction of the needle valve 30 away from the valve seat 24 will be referred to as a valve-opening direction. Furthermore, a seating direction of the needle valve 30 toward the valve seat 24 will be referred to as a valve-closing direction.

The fuel injection valve 1 includes a solenoid drive device, which drives the needle valve 30. The solenoid drive device includes a coil 40, a stationary core 50 and a movable core 60.

A spool 41 is placed on a radially outer side of the tubular member 11 and the non-magnetic portion 12 of the housing 10. The coil 40 is wound around the spool 41. A yoke 42, which is configured into a tubular body and is made of a magnetic material, covers an outer peripheral portion of the coil 40. The coil 40 is electrically connected to terminals 44 of a connector 43. When the coil 40 is energized through the connector 43, the coil 40 generates a magnetic field.

The stationary core 50 is configured into a generally cylindrical tubular body and is made of a magnetic material. The stationary core 50 is fixed to an inner peripheral wall of the tubular member 11 and an inner peripheral wall of the non-magnetic portion 12. A hole 51 is formed in the stationary core 50 such that the hole 51 axially extends along a central axis of the stationary core 50. A first spring 70 is inserted in the hole 51 of the stationary core 50. One end portion of the first spring 70 contacts the flange 31 of the needle valve 30, and the other end portion of the first spring 70, which is opposite from the one end portion of the first spring 70, contacts an adjusting pipe 71 that is securely press-fitted into an inside of the stationary core 50. A load of the first spring 70 is set depending on the amount of insertion of the adjusting pipe 71 into the inside of the stationary core 50. The first spring 70 urges the needle valve 30 toward the injection hole 23.

The movable core 60 is configured into a generally cylindrical tubular body and is made of a magnetic material. The movable core 60 is formed separately from the needle valve 30 and is axially placed on the injection hole 23 side of the stationary core 50.

The movable core 60 is placed radially inward of the housing 10 in a manner that enables axial reciprocation of the movable core 60 in the housing 10. In a deenergized state of the coil 40, a predetermined gap 90 is formed between the movable core 60 and the stationary core 50.

A center hole 61 is formed in the movable core 60 such that the center hole 61 axially extends through the movable core 60 at a center portion of the movable core 60. The needle valve 30 is received through the center hole 61 of the movable core 60. A portion of the needle valve 30, which is placed radially inward of the movable core 60, is slidable along an inner peripheral wall of the center hole 61 of the movable core 60. The needle valve 30 is reciprocatably received in the housing 10 such that the needle valve 30 is guided at two portions of the needle valve 30, i.e., the slidable portion 34 of the needle valve 30, which is axially located at the nozzle body 20 side, and the portion of the needle valve 30, which is located radially inward of the movable core 60.

The movable core 60 includes a plurality of communication holes 62. The communication holes 62 communicate between the gap 90, which is formed between the stationary core 50 and the movable core 60, and a gap 91, which is formed between the movable core 60 and the stopper 80. The axial moving speed of the movable core 60 is adjustable through setting of the number of the communication holes 62, the inner diameter(s) of the communication holes 62 and the location(s) of the communication holes 62. In the present embodiment, the number of the communication holes 62 is three, and these communication holes 62 are arranged one after another in the circumferential direction.

A second spring 72 is placed such that one end portion of the second spring 72 contacts an end surface of a recess 67 of the movable core 60, which is axially placed on the injection hole 23 side, and the other end portion of the second spring 72 contacts a stepped surface 73 of the holder 13. The second spring 72 urges the movable core 60 in the valve-opening direction. In the deenergized state of the coil 40, the second spring 72 exerts the urging force against the movable core 60, so that the fuel inlet 14 side end surface of the movable core 60 contacts the injection hole 23 side end surface of the flange 31 of the needle valve 30. Therefore, when the coil 40 is energized, the movable core 60 and the needle valve 30 are simultaneously moved together. Thus, the valve-opening response of the fuel injection valve 1 at the time of lifting the needle valve 30 away from the valve seat 24 is improved.

The urging force of the first spring 70 is set to be higher than the urging force of the second spring 72. Therefore, in the deenergized state of the coil 40, the seat portion 33 of the needle valve 30 is seated against the valve seat 24.

The stopper 80 is provided on the injection hole 23 side of the movable core 60. The stopper 80 is made of a non-magnetic material and includes a circular disk portion (a ring portion, an annular portion) 81 and a tubular portion 82. The tubular portion 82 axially extends from an inner peripheral edge part of the circular disk portion 81 toward the injection hole 23. An outer peripheral wall of the tubular portion 82 is press-fitted to an inner peripheral wall of the holder 13. Alternatively, the stopper 80 may be configured such that the circular disk portion 81 is press-fitted to the inner peripheral wall of the holder 13.

The circular disk portion 81 of the stopper 80 limits movement of the movable core 60 toward the injection hole 23 side to limit the amount of compression of the second spring 72 at the time of moving the movable core 60 toward the injection hole 23. In FIG. 3, the movable core 60 is indicated by a dotted line. As shown in FIGS. 2 and 3, a radial length (radial extent) L1 of a first contact surface 83 of the circular disk portion 81, which is located on the movable core 60 side, is larger than a radial length (radial extent) L2 of a second contact surface 66 of the movable core 60, which is located on the injection hole 23 side. That is, when the first contact surface 83 and the second contact surface 66 are projected onto an imaginary surface (imaginary plane) that is perpendicular to the axis of the needle valve 30, the second contact surface 66 is entirely received within the inside of the first contact surface 83. With this construction, a squeezing force, which is exerted at the time of colliding the second contact surface 66 against the first contact surface 83, and a linking force, which is exerted at the time of separating the second contact surface 66 away from the first contact surface 83, are increased. The squeezing force is a force of the fluid held between the first contact surface 83 and the second contact surface 66. The linking force is a force, which interferes with separation between two articles in the fluid.

As shown in FIG. 2, an inner diameter D1 of the tubular portion 82 of the stopper 80 is set to be slightly larger than an outer diameter D2 of the second spring 72 to limit tilting of the second spring 72. With this setting, the inner peripheral wall of the tubular portion 82 of the stopper 80 can axially guide the second spring 72. Thus, a predetermined orientation of the second spring 72 is maintained, and thereby the load of the second spring 72, which urges the movable core 60, is stabilized. Furthermore, a predetermined orientation of the movable core 60 is maintained, and thereby generation of an unintentional frictional force between the movable core 60 and the holder 13 or the non-magnetic portion 12 can be limited.

Next, the operation of the fuel injection valve 1 will be described.

The fuel, which is supplied from the fuel inlet 14 to the upstream passage 17, is filled in the inside passage 36 of the needle valve 30 and the downstream passage 19.

FIG. 2 shows the deenergized state of the coil 40. The needle valve 30 is urged by the first spring 70, so that the seat portion 33 is seated against the valve seat 24. The movable core 60 is urged against the injection hole 23 side end surface of the flange 31 of the needle valve 30 by the urging force of the second spring 72. At this time, the small gap 91 is formed between the movable core 60 and the stopper 80. The gap 91 between the movable core 60 and the stopper 80 is exaggerated in FIGS. 2 and 4. Actually, the axial size of the gap 91 is, for example, about 30  $\mu\text{m}$ .

Now, a valve-opening operation of the fuel injection valve 1 will be described.

When the coil 40 is energized, the magnetic field is generated by the coil 40. Therefore, as indicated by arrows B in FIG. 6, the magnetic flux flows through a magnetic circuit, which is formed by the stationary core 50, the tubular member 11, the yoke 42, the holder 13 and the movable core 60. The stopper 80 is made of the non-magnetic material. Therefore, the leakage of the magnetic flux from the holder 13 to the stopper 80 is reduced or limited. Thus, the density of the magnetic flux, which flows between the movable core 60 and the stationary core 50, is increased.

When the magnetic attractive force is exerted between the movable core 60 and the stationary core 50, the movable

core 60 is magnetically attracted to the stationary core 50, as indicated in FIG. 4. When the movable core 60 contacts the stationary core 50, the communication holes 62 of the movable core 60 are closed by the stationary core 50. Furthermore, the movable core 60 contacts the flange 31, so that the needle valve 30 and the movable core 60 are moved together in the valve-opening direction. As a result, the seat portion 33 is lifted away from the valve seat 24 to open the injection hole 23, and thereby the fuel is injected through the injection hole 23.

Next, a valve-closing operation of the fuel injection valve 1 will be described.

When the coil 40 is deenergized, the needle valve 30 is moved together with the movable core 60 in the valve-closing direction. As shown in FIG. 2, when the seat portion 33 of the needle valve 30 is seated against the valve seat 24, the fuel injection is stopped.

Thereafter, the movable core 60 is kept moving in the valve-closing direction by inertia. At this time, the urging force of the second spring 72 is exerted to reduce the moving speed of the movable core 60. As shown in FIG. 5, when the movable core 60 contacts the stopper 80, the movement of the movable core 60 in the valve-closing direction is limited. Therefore, the amount of compression of the second spring 72 is limited.

When the movable core 60 contacts the stopper 80, the communication holes 62 of the movable core 60 are closed by the stopper 80. The first contact surface 83 of the stopper 80 can entirely contact the second contact surface 66 of the movable core 60. Therefore, the contact pressure, which is exerted between the first contact surface 83 and the second contact surface 66 at the time of collision of the second contact surface 66 against the first contact surface 83, is relatively small. Furthermore, the squeezing force, which is exerted at the time of colliding the second contact surface 66 against the first contact surface 83, and the linking force, which is exerted at the time of separating the second contact surface 66 away from the first contact surface 83, are relatively large. Thereby, the damper effect, which reduces the moving speed of the movable core 60, is generated. Thus, when the movable core 60 rebounds from the stopper 80 after the collision of the movable core 60 against the stopper 80, the moving speed of the movable core 60 in the rebound motion of the movable core 60 away from the stopper 80 is reduced.

Furthermore, the axial size of the gap 91 between the movable core 60 and the stopper 80 is set to a value, which enables reduction of the collision force of the movable core 60 against the flange 31 of the needle valve 30 at the time of rebound of the movable core 60 toward the stationary core 50 to limit the secondary valve-opening movement of the needle valve 30 away from the valve seat 24.

Specifically, the resilient force, which is accumulated in the second spring 72, is reduced by the stopper 80, so that the moving speed of the movable core 60 in the rebound motion of the movable core 60 toward the stationary core 50 is reduced. Furthermore, the gap 91 between the movable core 60 and the stopper 80 is appropriately set, so that the collision force of the movable core 60 against the flange 31 of the needle valve 30 is reduced. Therefore, as shown in FIG. 2, when the movable core 60 contacts the flange 31 of the needle valve 30, the movement of the needle valve 30 in the valve-opening direction is limited. Thus, the secondary valve-opening movement of the needle valve 30 away from the valve seat 24 is advantageously limited.

Now, the advantages of the present embodiment will be described.

(1) In the present embodiment, when the energization of the coil 40 is turned off to place the coil 40 into the deenergized state in the valve-closing operation of the needle valve 30, the movable core 60 is moved together with the needle valve 30 toward the injection hole 23 by the urging force of the first spring 70. At this time, the movement of the movable core 60 toward the injection hole 23 is limited by the stopper 80, so that the movement of the movable core 60 toward the injection hole 23 is minimized. Therefore, the amount of compression of the second spring 72 is reduced, and thereby the urging force, which is accumulated in the second spring 72, is reduced.

Furthermore, the contact pressure, which is exerted between the first contact surface 83 of the stopper 80 and the second contact surface 66 of the movable core 60 at the time of collision of the second contact surface 66 of the movable core 60 against the first contact surface 83 of the stopper 80, is relatively small. Furthermore, the squeezing force, which is exerted between the first contact surface 83 and the second contact surface 66 at the time of collision of the second contact surface 66 against the first contact surface 83, and the linking force, which is exerted between the first contact surface 83 and the second contact surface 66 at the time of separation of the first contact surface 83 and the second contact surface 66 from each other, are relatively large. Therefore, the damping effect, which reduces the moving speed of the movable core 60, can be generated. Thus, the moving speed of the movable core 60 in the rebound motion of the movable core 60 away from the stopper 80 is reduced, and thereby the collision force of the movable core 60 against the needle valve 30 is reduced.

Furthermore, the axial size of the gap 91, which is formed between the stopper 80 and the movable core 60 in the deenergized state of the coil 40, is set to the value, which enables limiting of the secondary valve opening movement of the needle valve 30 away from the valve seat 24 by reducing the collision force of the movable core 60 against the flange 31 of the needle valve 30 at the time of the rebound of the movable core 60 toward the stationary core 50.

Therefore, the fuel injection valve 1 can limit the secondary opening of the injection hole 23, which results from the secondary valve-opening movement of the needle valve 30 away from the valve seat 24, at the time of valve-closing operation of the needle valve 30.

Furthermore, the contact pressure, which is exerted between the first contact surface 83 and the second contact surface 66 at the time of collision of the second contact surface 66 against the first contact surface 83, is reduced. Therefore, the durability of the stopper 80 and the durability of the movable core 60 can be improved.

(2) In the present embodiment, the movable core 60 has the communication holes 62. The communication holes 62 communicate between the gap 90, which is formed between the stationary core 50 and the movable core 60, and the gap 91, which is formed between the movable core 60 and the stopper 80. The axial moving speed of the movable core 60 in the reciprocating motion thereof is adjustable through setting of the location(s), the inner diameter(s) and the number of the communication holes 62. Therefore, the fuel injection valve 1 can limit the secondary valve-opening movement of the needle valve 30 away from the valve seat 24 at the time of valve-closing operation of the needle valve 30 and can improve the valve-opening response and the valve-closing response of the needle valve 30 at the time of energization and deenergization, respectively, of the coil 40.



(3) In the present embodiment, the tubular portion **82** of the stopper **80** can axially guide the second spring **72** along the inner peripheral wall of the tubular portion **82** of the stopper **80**. Thereby, the predetermined orientation of the second spring **72** is maintained. Thus, the load of the second spring **72** against the movable core **60** is stabilized, and the predetermined orientation of the movable core **60** is maintained. As a result, the generation of the unintentional frictional force between the movable core **60** and the inner peripheral wall of the housing can be limited, and thereby the smooth movement of the movable core **60** is maintained. Therefore, the fuel injection valve **1** can limit the secondary valve-opening movement of the needle valve **30** away from the valve seat **24** at the time of valve-closing operation of the needle valve **30** and can improve the valve-opening response and the valve-closing response of the needle valve **30** at the time of energization and deenergization, respectively, of the coil **40**.

(4) In the present embodiment, the inside passage **36** of the needle valve **30** communicates between the upstream passage **17** and the downstream passage **19** through the flow outlet **32**, which is formed at the radially inner side of the stopper **80**. In this way, even when the communication holes **62** of the movable core **60** are closed by the stationary core **50** or the stopper **80**, the fuel can flow between the upstream passage **17** and the downstream passage **19** through the inside passage **36** of the needle valve **30**.

(5) In the present embodiment, the stopper **80** is made of the non-magnetic material, so that the magnetic resistance of the stopper **80** is relatively large. Thus, the leakage of the magnetic flux to the stopper **80** can be limited at the time of energization of the coil **40**, so that the density of the magnetic flux between the movable core **60** and the stationary core **50** is increased. In this way, it is possible to improve the valve-opening response of the fuel injection valve **1**.

(6) In the present embodiment, the needle valve **30** and the movable core **60** are formed separately. Therefore, the collision force, which is exerted at the time of seating of the needle valve **30** against the valve seat **24**, is relatively small. Thus, the bounce, i.e., rebound of the needle valve **30** from the valve seat **24** is limited to limit the secondary injection of fuel through the injection hole **23**. Furthermore, the operational noise is reduced at the time of seating the needle valve **30** against the valve seat **24**.

#### Second Embodiment

FIG. 7 shows a fuel injection valve according to a second embodiment of the present disclosure. In the following embodiments, the components, which are similar to those of the first embodiment, will be indicated by the same reference numerals and will not be described again to avoid redundancy.

In the second embodiment, a stopper **84** is made only of a circular disk portion. That is, the stopper **84** is configured into the circular disk body (a ring body, i.e., an annular body). The outer peripheral wall of the stopper **84** is press-fitted to the inner peripheral wall of the holder **13**. Furthermore, the inner diameter **D3** of the stopper **84** is larger than the outer diameter **D2** of the second spring **72** to such a degree that the second spring **72** does not contact the stopper **84** upon tilting of the second spring **72**.

In the second embodiment, the structure of the stopper **84** is simplified, and thereby the stopper **84** can be easily manufactured. Thereby, the manufacturing costs can be reduced.

Furthermore, the contact between the second spring **72** and the stopper **84** is limited. Therefore, the generation of the unintentional frictional force between the second spring **72** and the stopper **84** can be limited.

#### Third Embodiment

FIG. 8 shows a fuel injection valve according to a third embodiment of the present disclosure. In the third embodiment, the stopper **85** and the holder **13** are formed integrally and seamlessly.

In the third embodiment, the stopper **85** can be manufactured only through management of a distance **H** between the stepped surface **73** of the holder **13** and the moveable core **60** side end surface of the stopper **85**. Thus, the number of points of the components, at which the size needs to be managed, can be reduced. Therefore, the clearance between the movable core **60** and the stopper **85** can be accurately formed.

#### Fourth Embodiment

FIGS. 9 and 10 show a fuel injection valve according to a fourth embodiment of the present disclosure.

Although it is difficult to see the gap **91** between the movable core **60** and the stopper **86** in FIG. 10, the axial size of the gap **91** is set to be about 30  $\mu\text{m}$  in the deenergized state of the coil **40** like in the first to third embodiments. Furthermore, in FIG. 10, the coil, the yoke and the spool are omitted for the sake of simplicity.

In the fourth embodiment, a stopper **86** is configured into a ring body (annular body). Specifically, an inner diameter **D4** of the stopper **86** of the fourth embodiment is larger than the inner diameter **D3** of the stopper **84** of the second embodiment. Therefore, the space, which is located radially inward of the stopper **86**, is widened, and the pressure loss of the fuel, which flows through the downstream passage **19**, is reduced.

An outer peripheral wall of the stopper **86** is securely press-fitted to the inner peripheral wall of the holder **13**. Furthermore, the injection hole **23** side end surface of the stopper **86** contacts the stepped surface **131** of the holder **13**.

In the present embodiment, the number of the communication holes **62**, which are arranged one after another in the circumferential direction in the movable core **60**, is four. Here, it should be noted that, for instance, the number of the communication holes **62** and the inner diameter(s) of the communication holes **62** can be freely set depending on a need. One end portion of each communication hole **62** is communicated with the gap **90**, which is formed between the movable core **60** and the stationary core **50**, and the other end portion of the communication hole **62** is communicated with the downstream passage **19**. In the contact state of the movable core **60**, in which the movable core **60** contacts the stopper **86**, about one half of the opening of the communication hole **62** opens to the downstream passage **19**.

In the fourth embodiment, the stopper **86** is formed as the simple ring body, so that the processing and the size management of the stopper **86** are relatively easy. Furthermore, since the profile of the stopper **86** is reduced, the manufacturing costs can be reduced, and the weight of the fuel injection valve **1** can be reduced.

Furthermore, the pressure loss of fuel, which flows through the downstream passage **19**, can be reduced by increasing the inner diameter of the stopper **86** and increasing the inside space of the stopper **86**.

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Even in the fourth embodiment, the stopper **86** limits the movement of the movable core **60** at the time of the valve-closing operation of the needle valve **30** to limit the amount of compression of the second spring **72**. That is, when the movable core **60** contacts the stopper **86**, the resilient force, which is accumulated in the second spring **72**, is reduced.

Furthermore, the axial size of the gap **91** between the movable core **60** and the stopper **86** is set to the value, which enables the reduction of the collision force of the movable core **60** against the flange **31** of the needle valve **30** at the time of rebound of the movable core **60** toward the stationary core **50** to limit the secondary valve-opening movement of the needle valve **30** away from the valve seat **24**.

Therefore, the fuel injection valve **1** can limit the secondary opening of the injection hole **23** by limiting the secondary valve-opening movement of the needle valve **30** away from the valve seat **24** at the time of valve-closing operation of the needle valve **30**.

Now, a modification of the above embodiments will be described.

In the above embodiments, the fuel injection valve, which injects the fuel into the internal combustion engine (more specifically, a cylinder of the internal combustion engine), is described. In a modification of the above embodiment(s), the fuel injection valve may be configured to inject fuel into, for example, an intake air passage of the internal combustion engine.

The present disclosure is not limited the above embodiments and modification thereof. That is, the above embodiments and modification thereof may be modified in various other ways without departing from the principle of the present disclosure.

What is claimed is:

1. A fuel injection valve comprising:
  - a housing that has:
    - an injection hole, through which fuel is injected;
    - a fuel passage that is communicated with the injection hole; and
    - a valve seat that is formed in an inner wall of the fuel passage;
  - a needle valve that is axially reciprocable, wherein:
    - the needle valve has a flange that radially outwardly projects;
    - the needle valve opens the injection hole when the needle valve is lifted away from the valve seat; and
    - the needle valve closes the injection hole when the needle valve is seated against the valve seat;
  - a coil that generates a magnetic field in an energized state of the coil;
  - a stationary core;
  - a movable core that is axially reciprocable and is placed on one axial side of the stationary core where the injection hole is located, wherein the movable core is engageable with the needle valve;
  - a first spring that axially urges the needle valve toward the injection hole;
  - a second spring that axially urges the movable core toward the stationary core with an urging force that is smaller than an urging force of the first spring, which axially urges the needle valve toward the injection hole; and
  - a stopper that is placed on one axial side of the movable core where the injection hole is located, wherein:
    - when a contact surface of the stopper contacts a contact surface of the movable core, the stopper limits move-

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ment of the movable core toward the injection hole to limit an amount of compression of the second spring; the movable core is movable between a first movable end position, which is located on one axial side where the stationary core is placed, and a second movable end position, which is located on another axial side where the stopper is placed;

the movable core is placed and is held in the first movable end position when the coil is energized;

the stopper directly contacts the movable core at the second movable end position of the movable core;

a gap is present between the movable core and the stopper to keep the movable core away from the second movable end position of the movable core when the coil is in a deenergized state;

the needle valve has a flow outlet that radially extends through the needle valve from an inner wall of an inside passage of the needle valve to an outer wall of the needle valve to conduct the fuel from an upstream passage of the fuel passage, which is located on an upstream side of the needle valve to a downstream passage of the fuel passage, which is radially defined between the needle valve and the housing, through the flow outlet of the needle valve; and

the contact surface of the stopper is located on an upstream side of the flow outlet of the needle valve in a flow direction of the fuel in a state where the needle valve is seated against the valve seat.

2. The fuel injection valve according to claim 1, wherein an axial size of the gap, which is formed between the stopper and the movable core in the deenergized state of the coil, is set to a value, which enables limiting of secondary valve opening movement of the needle valve away from the valve seat caused by abutment of the movable core against the flange of the needle valve, which is in turn caused by rebound of the movable core from the stopper after contacting of the movable core against the stopper due to inertial movement of the movable core together with the needle valve toward the injection hole upon changing of a state of the coil from the energized state to the deenergized state of the of the coil.

3. The fuel injection valve according to claim 1, wherein the movable core has at least one communication hole that communicates between a gap, which is formed between the movable core and the stationary core in a deenergized state of the coil, and a downstream passage, which is formed between an inner peripheral wall of the stopper and the valve element.

4. The fuel injection valve according to claim 1, wherein the stopper is configured into a ring body and is fixed to an inner wall of the housing.

5. The fuel injection valve according to claim 1, wherein: the stopper includes:

- a circular disk portion that is contactable with the movable core; and
- a tubular portion that axially extends from an inner peripheral edge part of the circular disk portion toward the injection hole; and

- the tubular portion of the stopper is configured to axially guide the second spring along an inner peripheral wall of the tubular portion.

6. The fuel injection valve according to claim 1, wherein: the stopper includes only a circular disk portion that is contactable with the movable core; and an inner diameter of the circular disk portion is set to a value that is larger than an outer diameter of the second

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spring and limits contact of the second spring against the circular disk portion upon tilting of the second spring.

7. The fuel injection valve according to claim 1, wherein the stopper is formed separately from the housing and is made of a non-magnetic material.

8. The fuel injection valve according to claim 1, wherein the stopper is formed integrally with the housing.

9. The fuel injection valve according to claim 5, wherein: the at least one communication hole of the movable core is closed by the stationary core when the movable core contacts the stationary core; and

the at least one communication hole of the movable core is closed by the stopper when the movable core contacts the stopper.

10. The fuel injection valve according to claim 1, wherein the needle valve has:

an inside passage that axially extends along a central axis of the needle valve; and

a flow outlet that radially extends from an inner wall of the inside passage to an outer wall of the needle valve.

11. The fuel injection valve according to claim 1, wherein the gap, which is formed between the stopper and the movable core in the deenergized state of the coil, is an uninterrupted axial gap, which radially extends from a radially inner peripheral edge of an end surface of the movable core to a radially outer peripheral edge of the end surface of the movable core.

12. The fuel injection valve according to claim 1, wherein the movable core is entirely lifted away from the stopper and is entirely separated from the stopper by the gap, which is formed between the stopper and the movable core, in the deenergized state of the coil.

13. The fuel injection valve according to claim 1, wherein the stopper is radially entirely spaced from and is thereby entirely separated from the valve element.

14. The fuel injection valve according to claim 1, wherein the stationary core directly contacts with the movable core at the first movable end position of the movable core.

15. The fuel injection valve according to claim 1, wherein the gap is present between the movable core and the stopper to keep the movable core away from the second movable end position of the movable core in the deenergized state of the coil at least in a time point immediately before energization of the coil.

16. The fuel injection valve according to claim 1, wherein one end portion of the movable core has:

the contact surface that contacts the contact surface of the stopper formed in a ring portion of the stopper, which is placed on a radially outer side of the valve element and radially outwardly projects, when the movable core collides against the ring portion of the stopper; and

a recess that is axially recessed away from the injection hole and is displaced from the contact surface of the movable core in a radial direction.

17. The fuel injection valve according to claim 16, wherein the contact surface of the movable core is axially spaced away from the contact surface of the ring portion of the stopper when the coil is deenergized.

18. The fuel injection valve according to claim 16, wherein the contact surface of the ring portion of the stopper covers the contact surface of the movable core when the movable core collides against the ring portion of the stopper.

19. The fuel injection valve according to claim 16, wherein a radial extent of the contact surface of the ring portion of the stopper is equal to or larger than a radial extent of the contact surface of the movable core.

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20. The fuel injection valve according to claim 16, wherein the second spring contacts an end surface of the recess of the movable core to axially urge the movable core toward the stationary core.

21. A fuel injection valve comprising: a housing that has: an injection hole, through which fuel is injected; a fuel passage that is communicated with the injection hole; and a valve seat that is formed in an inner wall of the fuel passage; a needle valve that is axially reciprocable, wherein:

the needle valve has a flange that radially outwardly projects; the needle valve opens the injection hole when the needle valve is lifted away from the valve seat; and the needle valve closes the injection hole when the needle valve is seated against the valve seat;

a coil that generates a magnetic field in an energized state of the coil; a stationary core;

a movable core that is axially reciprocable and is placed on one axial side of the stationary core where the injection hole is located, wherein the movable core is engageable with the needle valve;

a first spring that axially urges the needle valve toward the injection hole; a second spring that axially urges the movable core toward the stationary core with an urging force that is smaller than an urging force of the first spring, which axially urges the needle valve toward the injection hole; and

a stopper that is placed on one axial side of the movable core where the injection hole is located, wherein:

the stopper includes a ring portion, which is placed on a radially outer side of the needle valve and radially outwardly projects; and

when the movable core moves toward the injection hole and collides against a contact surface of the ring portion of the stopper through a contact surface of the movable core, the stopper limits further movement of the movable core toward the injection hole to limit an amount of compression of the second spring the needle valve has a flow outlet that radially extends through the needle valve from an inner wall of an inside passage of the needle valve to an outer wall of the needle valve to conduct the fuel from an upstream passage of the fuel passage, which is located on an upstream side of the needle valve to a downstream passage of the fuel passage, which is radially defined between the needle valve and the housing, through the flow outlet of the needle valve: and

the contact surface of the ring portion of the stopper is located on an upstream side of the flow outlet of the needle valve in a flow direction of the fuel in a state where the needle valve is seated against the valve seat.

22. The fuel injection valve according to claim 21, wherein:

the movable core is movable between a first movable end position, which is located on one axial side where the stationary core is placed, and a second movable end position, which is located on another axial side where the stopper is placed;

the movable core is placed and is held in the first movable end position when the coil is energized;

the stopper directly contacts the movable core at the second movable end position of the movable core; and

a gap is present between the movable core and the stopper to keep the movable core away from the second movable end position of the movable core when the coil is in a deenergized state.

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23. The fuel injection valve according to claim 21, wherein one end portion of the movable core has:  
the contact surface of the movable core; and  
a recess that is axially recessed away from the injection hole and is displaced from the contact surface of the movable core in a radial direction.

24. The fuel injection valve according to claim 23, wherein the contact surface of the movable core is axially spaced away from the contact surface of the ring portion of the stopper when the coil is deenergized.

25. The fuel injection valve according to claim 23, wherein the contact surface of the ring portion of the stopper covers the contact surface of the movable core when the movable core collides against the ring portion of the stopper.

26. The fuel injection valve according to claim 23, wherein a radial extent of the contact surface of the ring portion of the stopper is equal to or larger than a radial extent of the contact surface of the movable core.

27. The fuel injection valve according to claim 23, wherein the second spring contacts an end surface of the recess of the movable core to axially urge the movable core toward the stationary core.

28. The fuel injection valve according to claim 1, wherein in an imaginary plane, which is perpendicular to a central axis of the needle valve and includes the contact surface of the stopper, a surface area of the contact surface of the stopper is equal to or larger than one half of a cross-sectional area of a space radially defined between the housing and the needle valve.

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29. The fuel injection valve according to claim 1, wherein in an imaginary plane, which is perpendicular to a central axis of the needle valve and includes the contact surface of the stopper, a radial extent of the contact surface of the stopper is equal to or larger than a radial distance between the housing and the needle valve.

30. The fuel injection valve according to claim 1, wherein an inner peripheral edge part of the stopper does not contact the moveable core when the contact surface of the stopper contacts the contact surface of the movable core.

31. The fuel injection valve according to claim 21, wherein in an imaginary plane, which is perpendicular to a central axis of the needle valve and includes the contact surface of the ring portion of the stopper, a surface area of the contact surface of the ring portion of the stopper is equal to or larger than one half of a cross-sectional area of a space radially defined between the housing and the needle valve.

32. The fuel injection valve according to claim 21, wherein in an imaginary plane, which is perpendicular to a central axis of the needle valve and includes the contact surface of the ring portion of the stopper, a radial extent of the contact surface of the ring portion of the stopper is equal to or larger than a radial distance between the housing and the needle valve.

33. The fuel injection valve according to claim 21, wherein an inner peripheral edge part of the stopper does not contact the moveable core when the contact surface of the ring portion of the stopper contacts the contact surface of the movable core.

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